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(54) **Optical fibre transmission lines.**

(57) An optical fibre transmission line is installed by first installing a conduit (11) having one or more bores (12) and subsequently inserting flexible, lightweight optical fibre members (14) containing the optical fibres (22, 32) into the bores (12).

The optical fibre members (14) are propelled by employing the fluid drag of air, or another suitable gas, passed at high velocity through the bores (12).

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OPTICAL FIBRE TRANSMISSION LINES

This invention relates to optical fibre transmission lines, and in particular though not exclusively to methods, apparatus, and cable structures for their installation.

Optical fibre cables carrying optical fibre transmission lines have heretofore been installed by the same methods as conventional metal conductor cables, those methods usually involving pulling the cable with a pulling rope through a previously laid cable duct. Frequently the cable duct already contains one or more conventional cables at the time of installing the optical fibre cable.

Unlike the metal conductors of a conventional cable, the optical fibres are easily damaged by tensile stress. Such stress may, for example, propagate micro-cracks, leading to fibre breakage in the long term. It is, therefore, standard practice to reinforce optical fibre cables by providing a central strength member, usually one or more steel tension wires, about which the optical fibres are disposed. The strength member takes up, and thus increases the ability of the cable to withstand, tensile stresses accompanying installation of the cable.

Unfortunately, the central strength member usually provides insufficient protection against local stresses caused by pulling a further cable through the same duct. The conventional approach of installing at the outset optical fibre cables containing sufficiently large numbers of optical fibres to satisfy foreseeable future traffic demands is a way of overcoming this problem. In consequence, first time installation of optical fibre cables containing dozens or even hundreds of optical

fibres are currently envisaged despite the fact that to begin with a small fraction of the installed fibres would provide ample traffic carrying capacity. A further reason for installing optical fibre cables of comparatively large dimension is that the smaller the cross-section of the cable the more prone the cable becomes to wedging in between those cables already present in the duct.

The first time installation of large diameter optical fibre cables with high numbers of optical fibres, is, however, undesirable for a variety of reasons. Firstly, there are problems of a technical nature inherent in such cables, such as for example the difficulty of forming joints and of achieving the required high strength-to-weight ratios. Secondly, there are clear economical drawbacks in committing large resources to install intially unused fibre capacity, particularly in view of the comparatively recent origins of optical fibre technology which lead one to expect continued substantial reductions in the price and improvement in the quality of optical fibres. Thirdly, there is the serious risk of damaging in a single incident very large numbers of expensive optical fibres and, finally, there is an appreciable loss in flexibility when routing high density optical fibre transmission lines.

A method of installing optical fibres with pulling ropes and pull chords is described in "Sub-ducts: The Answer to Honolulu's Growing Pains", Herman S L Hu and Ronald T Miyahara, Telephony, 7 April 1980, pp 23 to 35. The installation method described there proceeds as follows: A section of existing 4-inch (100mm) duct is rodded and thereafter between one and three individual 1-inch (25mm) polyethylene tubes are inserted into the duct using pulling ropes. The polyethylene tubes form sub-ducts into which an optical fibre cable can be pulled

with the aid of a nylon pull chord which has previously been inserted into the sub-duct by means of a parachute attached to its leading end and pushed through the subduct with compressed air.

The method just referred to does deal with some of the problems discussed above, but only to a very limited extent. Thus, it enables fibre capacity to be increased in up to three stages, and separates the optical fibre cables from those cables already in the duct, thereby greatly reducing the liklihood of jamming, and hence overstressing, of the optical fibre cable.

It is an object of the present invention to overcome, or at least appreciably mitigate the majority of the aforementioned problems of installing optical fibre transmission lines.

It is another object to provide a method of installing optical fibre transmission lines which is comparatively simple and yet flexible and economical

According to the present invention a method of advancing a lightweight and flexible optical fibre member along a tubular pathway comprises propelling the fibre member along the pathway by fluid drag of a gaseous medium passed through the pathway in the desired direction of advance.

It will be appreciated that to generate sufficient fluid drag to propel the fibre member, the gaseous medium has to be passed through the pathway with a flow velocity much higher than the desired rate of advance.

The terms "lightweight and flexible" in respect of the optical fibre member are to be understood as meaning "sufficiently lightweight and flexible" for the fibre member to be propelled by the fluid drag.

Whether the fibre member is sufficiently lightweight and flexible and the flow velocity sufficiently high is readily determinable by a simple trial and error experiment, guided, if necessary, by the theoretical model discussed below.

The flow velocity of the gaseous medium may be steady or may be suitably varied, for example either between a first velocity producing no, or insufficient, fluid drag to propel the fibre member, and a second velocity producing sufficient fluid drag to propel the fibre member, or between a first and a second velocity both producing sufficient fluid drag for propelling the fibre member. Conveniently the variations in velocity take the form of repeated abrupt changes between the first and second velocity.

The aforementioned variations in flow velocity may include periods during which the flow is reversed with respect to the desired direction of advance of the fibre member.

It is to be understood that more than one fibre member may be propelled along the same tubular pathway.

A fibre member may, for example, comprise a single optical fibre, protected by at least a primary coating but preferably contained within an outer envelope. Alternatively, a fibre member may comprise a plurality of optical fibres contained within a common envelope.

The envelope may be loosely or tightly surrounding the fibre or fibres.

The method may be used for insertion of an optical fibre member into, or its withdrawal, from the pathway.

The gaseous medium is chosen to be compatible with the environment in which the invention is performed, and in ordinary environments will be a non-hazardous gas or gas mixture.

With the proviso about compatibility with the environment, the gaseous medium is preferably air or nitrogen.

The tubular pathways and/or the fibre members are conveniently but not necessarily of circular cross-section, and the fibre member is always smaller than the pathway.

In practice the pathway internal diameter will generally be greater, and frequently much greater than 1mm, and the external diameter of the fibre member greater than 0.5mm.

A preferred range of diameters for the pathway is 1 to 10mm, conveniently between 3 and 7mm, and a preferred range of diameters for the fibre members is 1 to 4mm, although much larger diameters may be used provided the fibre member is sufficiently lightweight and flexible. The diameter of the fibre members is preferably chosen to be greater than one tenth, and conveniently to be about one half of the pathway diameter or greater (and appropriately less, of course, if more than one fibre member is to be propelled through the same pathway).

Insertion of a fibre member by means of the fluid drag of a gas passing over the fibre member has several advantages over methods involving pulling an optical fibre cable with a pull cord.

Firstly, the extra step of providing a pull cord is elimated.

Secondly, using the fluid drag of a gaseous medium produces a distributed pulling force on the fibre member. This is particularly advantageous if the installation route contains one or more bends. If, as would be the case with a pulling cord, the pulling force were concentrated at the leading end of the fibre member, any deviation of the pathway from a straight line would

greatly increase friction between the fibre member and the internal walls of the pathway, and only a few bends would be sufficient to cause locking of the fibre member. The distributed pulling force produced by the fluid drag, on the other hand, enables bends to be negotiated fairly easily, and the number of bends in a given installation is no longer of much significance.

Thirdly, the fluid drag substantially reduces overall pulling stress on the fibre member and so permits the fibre member to be of relatively simple and cheap construction.

Furthermore, because the fibre member is not subjected to any substantial pulling stress during installation, little allowance, if any, needs to be made for subsequent relaxation.

According to a further aspect of the present invention, a method of installing an optical fibre transmission line comprises installing a conduit having one or more ductlets providing tubular pathways and, after installation of the conduit, inserting by the aforesaid method using fluid drag one or more fibre members into the associated ductlets as required.

Installing optical fibre transmission lines by this method has several advantages over conventional techniques.

Firstly, since the conduit is installed without containing any optical fibres, conventional rope pulling and similar techniques may be freely employed for installing the conduit.

Secondly, the capacity of a transmission line can readily be adapted to requirements. Thus, while initially only one or two fibre members may be sufficient to carry the traffic the conduit may contain a much larger number of ductlets than are required at the time of installation, and further fibre members may be inserted later on as and

when needed. The conduit of the present invention is cheap compared to the cost of the fibres, and spare ductlets to accommodate further fibres as and when extra capacity is required can thus be readily incorporated without adding more than a small fraction to overall costs.

The method of the present invention also permits the installation of improved later generations of optical fibre transmission lines. It is possible, for example, to install at first one or more fibre members incorporating multimode fibres, and at a later date add, or replace the installed multimode fibre members with fibre members incorporating monomode fibres. Installed fibre members may conveniently be withdrawn from the ductlet, and replacement fibre members be inserted by using the aforesaid method of propelling by fluid drag of a gaseous medium.

According to yet another aspect of the present invention, an optical fibre cable comprises a conduit including one or more ductlets forming tubular pathways and capable of loosely accommodating an optical fibre member, and at least one optical fibre member inserted by the aforementioned method using fluid drag.

The conduit may be rigid or flexible.

Where the conduit includes more than one ductlet, the ductlets are conveniently formed by bores in the material of the conduit. The term "bore", like the word "tubular" is understood in this context to include circular and other suitable shapes of cross-sectional area.

Alternatively, the conduit may comprise a plurality of individual tubes enveloped by a common outer sheath.

It will be appreciated that the present invention largely avoids the risk, inherent in handling optical fibre cables with a large number of fibres, of accidentally damaging before or during installation in a single event a large number of expensive optical fibres.

The present invention also enables the installation of continuous optical fibres over several installation lengths without joints.

Furthermore, individual fibre members routed through the conduit can be routed, without requiring fibre joints, into different branch conduits at junction points.

The present invention will now be explained further by way of example and with reference to the accompanying drawings of which;

Figure 1 is a cross section through a conduit suitable for implementing the invention;

Figures 2 and 3 are relatively enlarged cross-sections through fibre members;

Figure 4 is a schematic diagram of apparatus for inserting fibre members into ductlets by fluid drag;

Figure 5 is a schematic drawing of a junction between a trunk and a branch conduit;

Figure 6 is a schematic diagram to illustrate notation used in drag force calculations;

Figure 7 is a schematic section of a modified drive unit; and

Figure 8 is a graph of drag force vs pressure.

Referring first to the Figure 1, there is shown a conduit 11 incorporating six ductlets 12, one of which contains a fibre member 14, and a core 13.

The conduit 11 is made of extruded polymer or other suitable material, the ductlets, or bores, 12 being formed in the conduit during its extrusion. The central core 13 contains copper wire pairs required for testing operations during and after installation, repeater supervision, power supply, and the like. Alternatively, or additionally, the core 13 may incorporate reinforcements, for example tension wires, to take up the tension forces during installation of the conduit.

Where required, the conduit may be surrounded by a water barrier (not shown).

The copper wire pair for testing can be omitted from the core 13 if suitable alternative testing facilities are available, such as, for example testing methods using optical fibres inserted subsequently into the conduit as described below.

Figure 2 is a cross-section through a fibre member 21 which is in a form particularly suited for installation by fluid drag. The fibre member 21 comprises several optical fibres 22 lying loosely in a polymer sheath 23. In view of the virtual absence of any pulling stress during installation of a fibre member by fluid drag, the fibre member 21 does not require reinforcement. The relatively simple construction also leads to lower production costs, as well as making the fibre member 21 comparatively light, thereby enabling easy installation by fluid drag.

In certain circumstances it may be desirable to provide a reinforced fibre member, and Figure 3 is a cross-section through such a fibre member 31 which, provided it is made light enough and flexible enough, is suitable for insertion by fluid drag into a ductlet 12 of the conduit 11 of Figure 1. The fibre member 31 consists of a plurality of optical fibres 32 arranged round a strength member 33 and enclosed in a polymer sheath 34..

The installation of an optical transmission line proceeds as follows:

The flexible conduit 11 is installed into an existing duct (not shown) by conventional methods such as pulling with a pulling rope.

Because the conduit 11 does not contain any optical fibres at this stage, the conduit 11 can be handled in the same way as an ordinary cable, and no special care needs

to be taken over and above that customary in installing conventional metal conductor cables. If required, it is also possible at this stage, that is before the conduit contains any optical fibres, to pull a further conduit through the duct to provide spare capacity.

Furthermore, since the conduit can readily be made of an external diameter matching that of cables already in the duct, wedging is less likely to occur than with a standard, smaller diameter optical fibre cable.

Once installed, optical fibre members such as 21 and 31 shown in Figure 2 or 3 are inserted into as many of the ductlets 12 as is required.

Instead of the afore-described fibre members 21 and 31 of near circular cross-section, the fibre members may, for example, be so-called ribbons, in which a thin, wide sheath encloses an optical fibre or a plurality of optical fibres lying in the same plane.

Manufacture of the conduit 11 is cheap compared to the optical fibres in the fibre members 21 or 31 which it is designed to carry, and spare ductlets 12 for future expansion can readily be incorporated at the extrusion stage of the conduit 11 without adding unduly to the overall cost. The conduit may be manufactured by adapting conventional cable manufacturing processes such as, for example, extrusion.

A gas flowing past the surface of a solid object produces a drag force which largely depends on the velocity of the gas relative to the surface. The Applicants have found that this drag force can be made sufficiently large to pull a lightweight optical fibre member 21, or 31 into a tubular pathway such as, for example, a ductlet 12 of the aforementioned conduit 11.

In experiments, the flow velocity, or the flow rate, of air through a given pathway has been found to depend approximately linearly on the pressure difference between opposite ends of the pathway, with the slope of the dependency indicating that flow at useful flow rates is predominantly turbulent.

For a given pressure difference, the flow rate varies with the size of the free cross sectional area of the bore, while the drag force on a fibre member present in a bore varies with the flow rate and the surface area of the fibre member. The drag force has been optimised in experiments by varying these parameters and, in particular, by choosing an appropriate ratio of bore diameter to fibre member diameter.

Experiments have been performed using a bore diameter of 7mm. The optimum fibre member diameter for this bore size has been found to lie between 2.5 and 4mm. A pressure below 80 p.s.i. (approximately 5.6 kgs/cm^2), usually about 40 p.s.i. has been found sufficient to insert fibre members of up to 3.5 gram per metre (gr/m) over lengths of 200 metres. A fibre member with 2 gr/m is easily installed over this length.

The theoretical value for the drag forces for these dimensions has been calculated in the manner described below with reference to Figure 6 to be 2.5 gr/m. Lower practical values are believed to be due to the tendency of the fibre members 21, 31 to acquire "set" while on the supply reel. This set would appear to force the fibre member 21, 31 against the wall of the bore 12, thereby increasing friction.

Suitable texturing or shaping of the fibre member surface may lead to drag forces higher than those presently experienced.

It should be noted here that using fluid drag to insert fibre members into tubular pathways differs significantly from the method described in the above mentioned article of inserting pull cords by means of parachutes. The parachute is propelled by the pressure difference between the air in front of and the air behind the parachute, and the velocity of the air relative to the advancing cord is only minimal and the pulling force is localised at the point of attachment of the parachute. In contrast, using fluid drag requires a relatively high flow of fluid relative to the surface of the fibre members.

Also, unlike the use of parachutes or potential other methods of inserting fibre members into the tubular pathways, using fluid drag produces a uniformly distributed pulling force on the fibre member. This reduces the strain on the optical fibres within the fibre member to very low values.

In ordinarily pulling a fibre member through a bend enclosing an angle θ, the tension of the leading end, T_2 is related to the tension T_1 at the trailing end $T_2/T_1 = e^{\mu\theta}$ where μ is the coefficient of friction. Even a small number of bends in the pathway may therefore result in an unacceptably high force being required at the leading end if locking of the fibre member is to be avoided. In contrast, the distributed pulling force produced by fluid drag is applied evenly along the fibre member, including in bends, and permits a large number of bends to be easily and speedily negotiated without any undue stress on the fibre member.

Figure 4 illustrates apparatus for feeding fibre members into tubular pathways such as the ductlets 12 of the conduit 11 of Figure 1. The apparatus consists of a feedhead 41 which contains a straight bore 44 connected at one end, its outlet end 42, to a flexible tube 49, and at

the other end, its inlet end 43, to a supply reel (not shown). The head 41 also contains an inlet 45 for air. The outlet end 42 and the bore 44 are substantially larger in cross sectional area than fibre member 46. The aperture of the inlet end 43 is only slightly larger in cross sectional area than that of the fibre member 46. This arrangements forms an air block which presents a relatively large flow resistance to air and helps prevent air escaping through the inlet duct 43. The tube 49 is inserted into one of the ductlets of the conduit 11. Suitable seals between the feedhead 41 and the tube 49, and the tube 49 and the ductlet 12 prevent undesirable escape of the air.

In use the fibre member 46 is fed into the inlet end 43 of the feedhead 41 by means of a pair of rubber drive wheels 47 and 48, driven by a constant torque driving mechanism (not shown). Air is fed into the bore 44 through the air inlet 45 and hence is directed through the tube 49 into the ductlet 12. The optical fibre member 46 is pushed through the inlet end 43 of the feedhead into the bore 44 and onwards into the tube 49. Pushing of the fibre member 46 continues until the surface area of the fibre member which is exposed to the air flow is sufficiently large to produce a drag force to cause the further advance of the fibre member 46 through the tube 49 and the ductlet 12, while the rate of feed is controlled by means of the aforementioned rubber drive wheels 47 and 48.

Figure 5 shows a branching connection between an optical fibre trunk line 51 and a branch line 52, each comprising a conduit 53 and 54 respectively and one or more fibre members 55 and 56. Since, as described above, the fibre members are individually inserted into the ductlets of the trunkline conduit 53, individual fibre

members 55 can be routed from the trunk conduit 53 into the branch conduit 54 as required, while other fibre members 56 continue to the adjacent section 53a of the trunkline conduit.

Referring now also to Figure 6, the drag force on the fibre member 64 within the bore 63 of a ductlet, or tube, 62 on account of turbulent air flow through the bore 63 can be calculated as discussed below.

These calculations show that what has been called fluid drag or drag force above is, in fact, a composite force, of which the major proportion is normally due to viscous drag, and at least one other important component due to a hydrostatic force, f' below. It will be appreciated that the exact composition of the drag force does not affect the principles of the invention but the more detailed analysis below can be used to optimise the parameters involved in carrying out the invention, and to obtain some guidance for trial and error experiments.

The pressure difference between the tube ends can be equated to a shear force distributed over the inner surface of the bore 63 and the outer surface of the fibre member 64. Thus, one has, for a small element of length Δl producing a pressure drop Δp

$$\Delta p \pi (r_2^2 - r_1^2) = F \qquad (1)$$

where r_2 = outer tube bore radius, r_1 = inner tube radius and F is the viscous drag force on the inner and outer walls of the elemental length.

If is it now assumed that the force F is distributed evenly over the area of the inner and outer

walls, that is to say the external wall of the fibre member and the internal wall of the ductlet respectively, the drag force, f, on the fibre member per unit length is:-

$$f = \frac{F}{\Delta l}\left[\frac{2\pi r_1}{2\pi(r_1 + r_2)}\right] = \frac{\Delta p \pi r_1 (r_2 - r_1)}{\Delta L} \qquad (2)$$

which gives, in the limit, the drag force on the fibre member per unit length,

$$f = \pi r_1 (r_2 - r_1)\frac{dp}{dl} \qquad (3)$$

In addition, we must consider the force produced by the pressure difference acting on the cross-sectional area of the fibre member. This is locally proportional to the pressure gradient and therefore is distributed over the installed length of the fibre member in the same way as the viscous drag force, leading to an additional force

$$f' = \frac{\Delta p}{\Delta l}\pi r_1^2 \qquad (4)$$

giving a total force per unit length of

$$f_{TOT} = \frac{dp}{dt}\pi r_1 r_2 \qquad (5)$$

In order to get an initial estimate of this it is assumed that the pressure drops linearly over the length of the bore, whether filled by the fibre member or not. Equation 5 is then plotted, for the case of the 6mm bore diameter with 2.5mm O.D. fibre member, in Figure 8, for a length of 300m. Since pressure is normally quoted in psi it has been retained here for the sake of convenience.

Coefficients of friction of around 0.5 have been measured for the polyethylene and polypropylene fibre members against a polyethylene bore wall. Therefore, with a fibre member weighing 3gms/m we could expect to install a 300m length with around 55 psi pressure. Any extra drag force over that required to overcome friction would appear at the start end as a gradually increasing tension in the fibre member as installation proceeds.

Figure 7 shows in diagrammatic form the arrangement of the modified drive unit discussed with reference to Figure 4, in which the only major change lies in incorporating the drive wheels 77 and 78 within the feedhead 71.

As the foregoing discussion with reference to Figure 6 has illustrated, the viscous drag force is accompanied by a hydrostatic force, the force f' of equation 5 above. This force f' has been found to oppose the insertion of the fibre member into the drive unit, making the incorporation of the drive wheels 77 and 78 into the drive unit preferable. The force f', referred above as the hydrostatic potential must be overcome when introducing the fibre member into the pressurised areas. The drive wheels would be driven by a torque just sufficient to overcome this potential.

The drive wheels are incorporated into the pressurised cavity 74 and thus the force on the fibre member necessary to overcome the hydrostatic potential is tensile. If the wheels were outside the drive unit, this force would be compressive, and there would be tendency for the fibre member to buckle.

For convenience the drive unit may be made to split along the fibre member axis, and perpendicular to the diagram, or in some other plane. The air seals 72, 73 may be, for example, rubber lips, or narrow channels.

In operation, a fibre member 76 fed into the drive unit would be automatically taken up by the drive wheels with just enough force to overcome the hydrostatic potential, and fed on along the ductlet 12. The fluid drag of the air flowing down the ductlet 12 causes the fibre member 76 to be pulled along the ductlet 12 as the installation proceeds. This means that such a drive unit can be placed between two adjoining sections of conduit so that a fibre member emerging from a ductlet in the first conduit can be fed into the appropriate ductlet of the second. Thus, an installation could consist of a fibre member 76 running through a number of conduits using two or more drive units in tandem, possibly without supervision.

It will be appreciated that it is possible to blow compounds in liquid or powder form along the ductlet prior to, or during installation in order to provide lubrication for the fibre members. Powdered talc is an example of a suitable lubricant.

The ductlets may, for example, also be formed in a power cable, or in a conventional subscriber line, to allow subsequent installation of optical fibre members. In the latter case, to avoid ingress of water, the ductlet may be sealed until the time of installation of the fibre members.

CLAIMS

1. A method of advancing a lightweight and flexible optical fibre member (14) along a tubular pathway (12) comprising propelling the fibre member (14) along the pathway (12) by fluid drag of a gaseous medium passed through the pathway (12) in the desired direction of advance.

2. A method as claimed in claim 1 wherein the gaseous medium is passed through the pathway (12), at a steady flow velocity.

3. A method as claimed in claim 1 wherein the gaseous medium is passed through the pathway (12) at a flow velocity which is repeatedly changed abruptly between a first and second velocity.

4. A method as claimed in any preceding claim wherein the gaseous medium is compressed air.

5. A method as claimed in any preceding claim wherein the gaseous medium is nitrogen.

6. A method of installing optical transmission lines comprising installing a conduit having one or more ductlets (12) forming tubular pathways and inserting optical fibre members (14) into associated ductlets (12) by a method as claimed in any one of claims 1 to 4.

7. A method as claimed in claim 6 wherein the conduit (11) is a flexible conduit installed by a conventional cable installation technique.

8. A method as claimed in any preceding claim using tubular pathways (12) and optical fibre members (14) of circular cross-section.

9. A method as claimed in any preceding claim using optical fibre members of a diameter greater than one tenth the diameter of the tubular pathway.

10. An optical fibre cable structure comprising a conduit (11) having one or more ductlets (12) capable of loosely accommodating an optical fibre member (14) and at least one optical fibre member (14) inserted into an associated ductlet by a method according to any one of claims 1 to 5.

11. A structure as claimed in claim 10 wherein the conduit is flexible.

12. A structure as claimed in claim 10 or 11 wherein the fibre member (14) comprises a plurality of optical fibres (22, 32) contained in a common envelope (22, 34).

13. A structure as claimed in any one of claims 7 to 9 wherein the fibre member (14) contains at least one single mode optical fibre.

14. A structure as claimed in any one of claims 10 to 13 wherein the ductlets have a diameter greater than 1mm and the fibre member or fibre members have a diameter greater than 0.5mm.

15. A structure as claimed in claim 14 wherein the ductlets have a diameter of between 1mm and 10mm.

16. Apparatus for performing the method according to any one of claims 1 to 9 comprising a feed head (41, 71) having a hollow substantially rectilinear passage (44, 74) extending therethrough, said passage being provided with an inlet end (43, 73) and an outlet end (42, 72) to receive and dispense respectively an optical fibre member (46, 76), and the outlet end (42, 72) being arranged to provide sealing coupling to a tubular pathway, having a further passage (45, 75) to supply a gaseous medium to said passage (44, 74), and being provided with a pair of constant torque driven wheels (47, 48: 77, 78) adapted to

engage and control advance of the optical fibre member (46, 76) towards the tubular pathway (12).

17. Apparatus as claimed in claim (16) wherein said drive wheels (77, 78) are located within the feedhead (71).

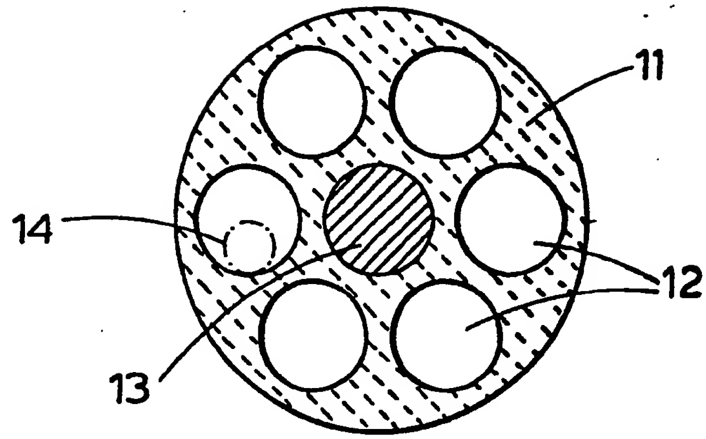


Fig. 1

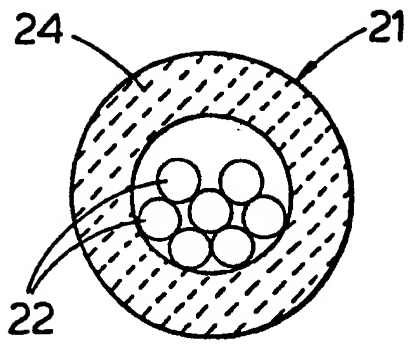


Fig. 2

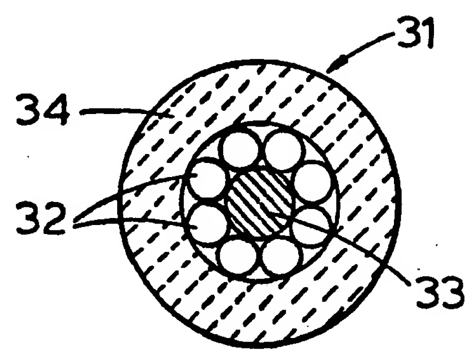


Fig. 3

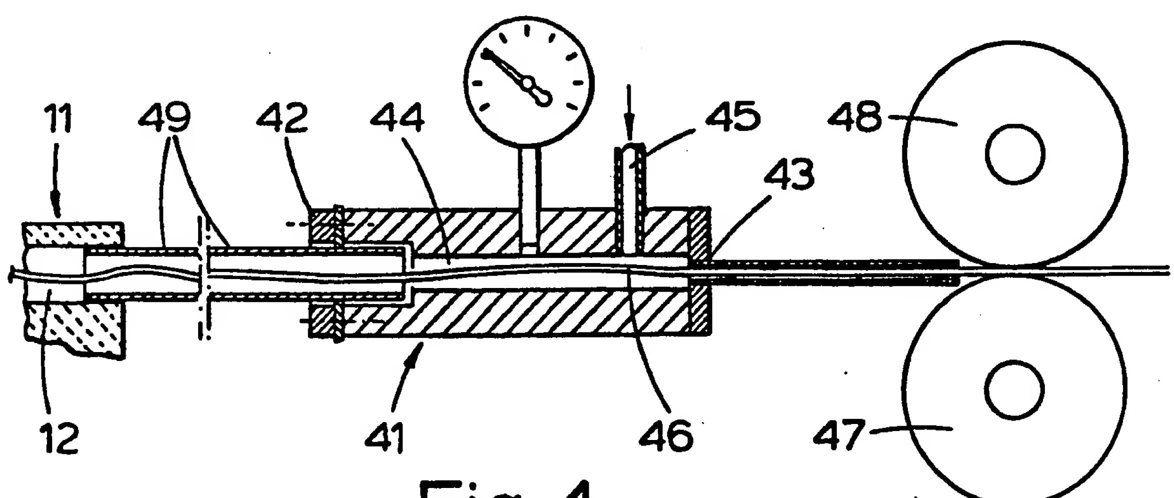


Fig. 4

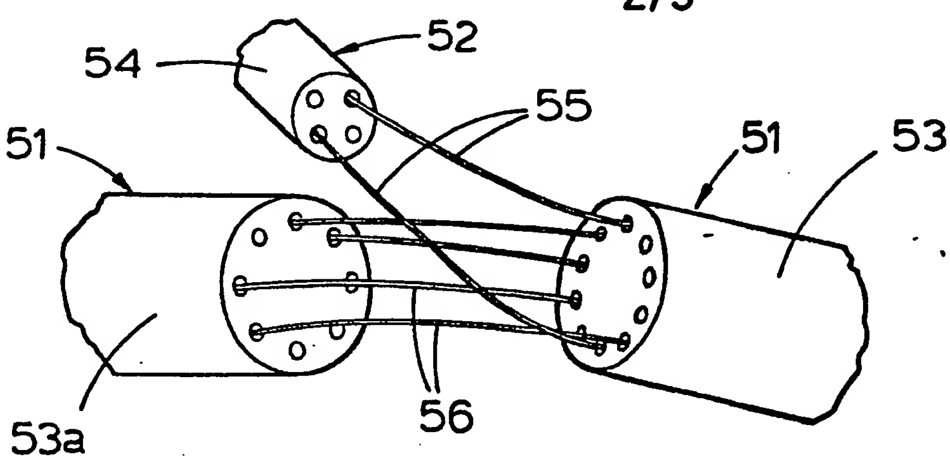


Fig.5

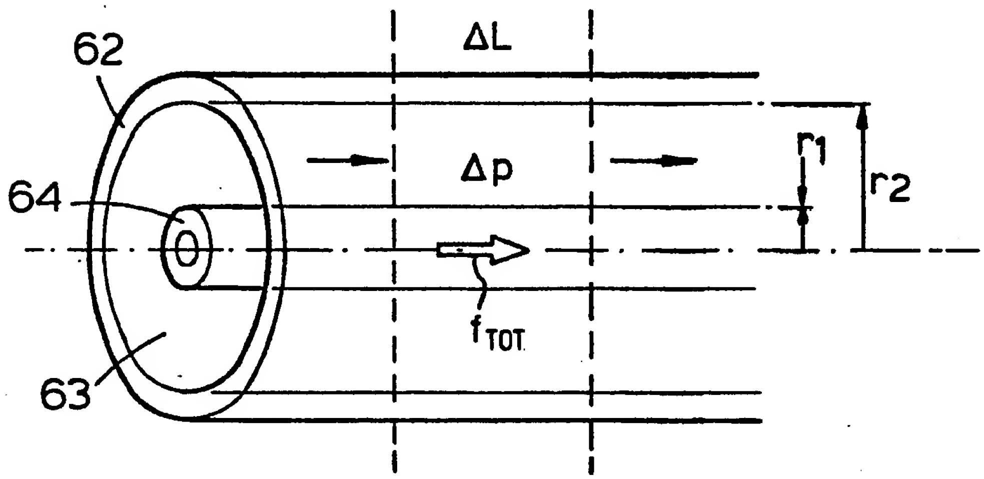


Fig.6

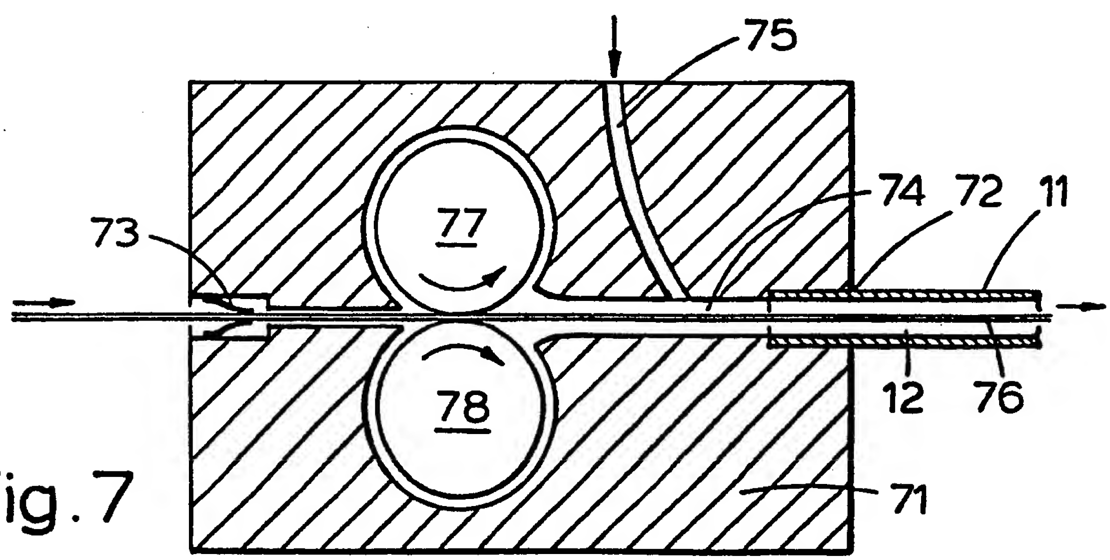
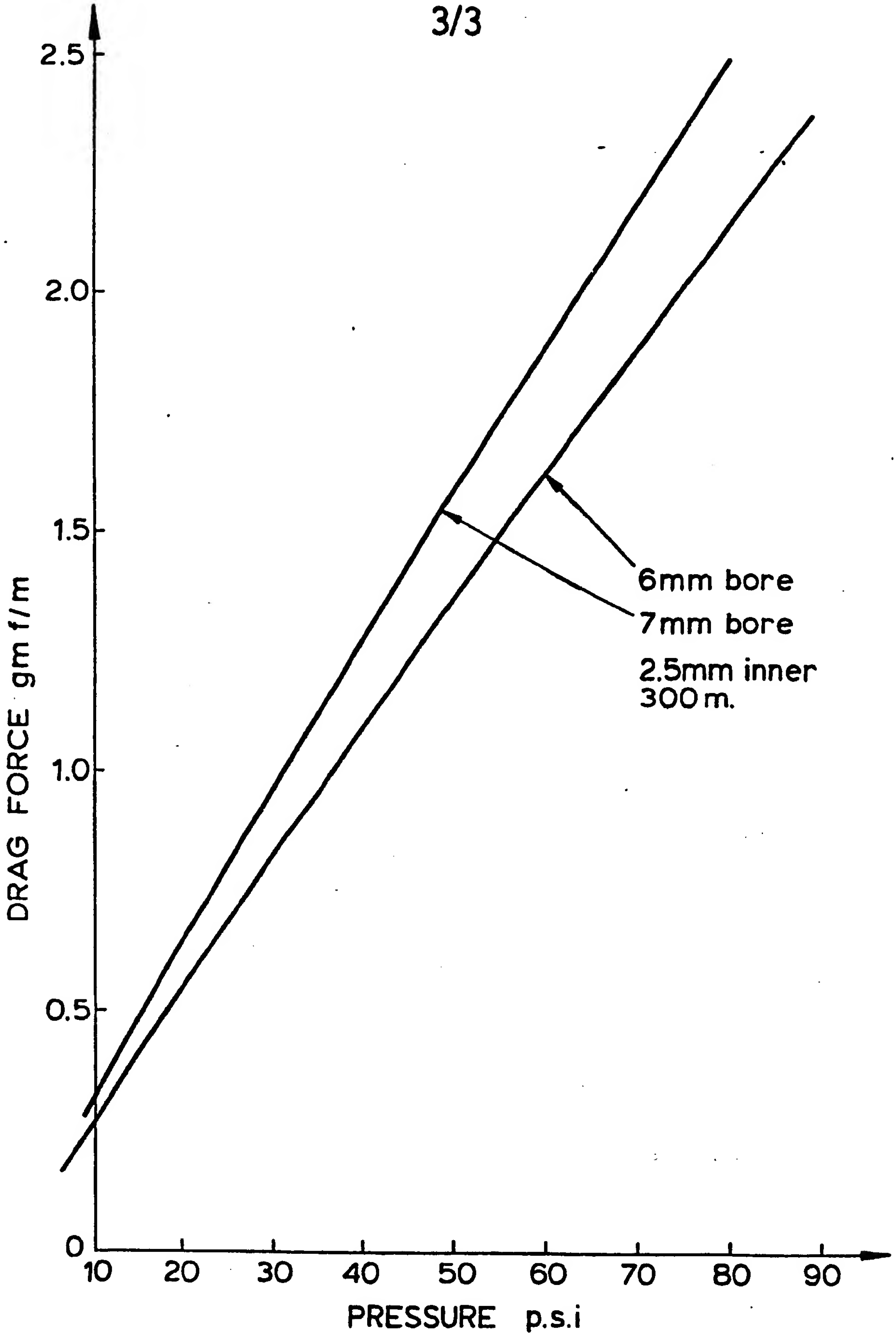


Fig.7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2.5
2.0
1.5
1.0
0.5
0
10
20
30
40
50
60
70
80
90
PRESSURE p.s.i
6mm bore
7mm bore
2.5mm inner
300m.

Fig. 8

0108590

European Patent Office

EUROPEAN SEARCH REPORT

Application number

EP 83 30 6636

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 3)
X	DE-A-2 507 583 (SIEMENS) * page 4; figure 3 *	1,2,3	G 02 B 5/16
A	DE-A-3 000 109 (CISE) * page 5; page 6, lines 1-7; claims; figures *	4,5,7	
A	US-A-4 248 035 (R.P. SKILLEN) * abstract; figures *	4	
A	US-A-4 185 809 (N. JONNES) * abstract; figures *	4	

TECHNICAL FIELDS SEARCHED (Int. Cl. 3)

G 02 B
H 02 G

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	21-02-1984	PFAHLER R.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
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T : theory or principle underlying th invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

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Description

This invention relates to optical fibre transmission lines, and in particular though not exclusively to methods of providing an optical communications route and apparatus for installing optical fibre transmission lines.

Optical fibre cables carrying optical fibre transmission lines have heretofore been installed by the same methods as conventional metal conductor cables, those methods usually involving pulling the cable with a pulling rope through a previously laid cable duct. Frequently the cable duct already contains one or more conventional cables at the time of installing the optical fibre cable.

Unlike the metal conductors of a conventional cable, the optical fibres are easily damaged by tensile stress. Such stress may, for example, propagate micro-cracks, leading to fibre breakage in the long term. It is, therefore, standard practice to reinforce optical fibre cables by providing a central strength member, usually one or more steel tension wires, about which the optical fibres are disposed. The strength member takes up, and thus increases the ability of the cable to withstand, tensile stresses accompanying installation of the cable.

Unfortunately, the central strength member usually provides insufficient protection against local stresses caused by pulling a further cable through the same duct. The conventional approach of installing at the outset optical fibre cables containing sufficiently large numbers of optical fibres to satisfy foreseeable future traffic demands is a way of overcoming this problem. In consequence, first time installation of optical fibre cables containing dozens or even hundreds of optical fibres are currently envisaged despite the fact that to begin with a small fraction of the installed fibres would provide ample traffic carrying capacity. A further reason for installing optical fibre cables of comparatively large dimension is that the smaller the cross-section of the cable the more prone the cable becomes to wedging in between those cables already present in the duct.

The first time installation of large diameter optical fibre cables with high numbers of optical fibres, is, however, undesirable for a variety of reasons. Firstly, there are problems of a technical nature inherent in such cables, such as for example the difficulty of forming joints and of achieving the required high strength-to-weight ratios. Secondly, there are clear economical drawbacks in committing large resources to install initially unused fibre capacity, particularly in view of the comparatively recent origins of optical fibre technology which lead one to expect continued substantial reductions in the price and improvement in the quality of optical fibres. Thirdly, there is the serious risk of damaging in a single incident very large numbers of expensive optical fibres and, finally, ther is an appreciable loss in flexibility when routing high density optical fibre transmission lines.

A method of installing optical fibres with pulling ropes and pull chords is described in "Sub-ducts: The Answer to Honolulu's Growing Pains", Herman S. L. Hu and Ronald T. Miyahara, Telephony, 7 April 1980, pp 23 to 35. The installation method described there proceeds as follows: A section of existing 4-inch (100 mm) duct is rodded and thereafter between one and three individual 1-inch (25 mm) polyethylene tubes are inserted into the duct using pulling ropes. The polyethylene tubes form sub-ducts into which an optical fibre cable can be pulled with the aid of a nylon pull chord which has previously been inserted into the sub-duct by means of a parachute attached to its leading end and pushed through the subduct with compressed air.

The method just referred to does deal with some of the problems discussed above, but only to a very limited extent. Thus, it enables fibre capacity to be increased in up to three stages, and separates the optical fibre cables from those cables already in the duct, thereby greatly reducing the likelihood of jamming, and hence overstressing, of the optical fibre cable.

In a similar prior art system disclosed in US—A—4,185,809, the cable is directly attached to a pulling plug that is propelled by fluid through a conduit.

It is an object of the present invention to overcome, or at least appreciably mitigate the majority of the aforementioned problems of installing optical fibre transmission lines.

It is another object to provide a method of installing optical fibre transmission lines which is comparatively simple and yet flexible and economical.

According to the present invention a method of moving a lightweight and flexible optical fibre transmission line comprising one or more optical fibres along a previously installed tubular pathway thereby to provide an optical communications route comprises propelling the fibre member along the pathway by fluid drag of a gaseous medium passed through the pathway in the desired direction of movement and passing over the transmission line at a relatively high average flow velocity.

It will be appreciated that to generate sufficient fluid drag to propel the fibre member, the gaseous medium has to be passed through the pathway with a flow velocity much higher than the desired rate of advance.

The terms "lightweight and flexible" in respect of the optical fibre member are to be understood as meaning "sufficiently lightweight and flexible" for the fibre member to be propelled by the fluid drag.

Whether the fibre member is sufficiently lightweight and flexible and the flow velocity sufficiently high is readily determinable by a simple trial and error experiment, guided, if necessary, by the theor tical model discussed below.

The flow vel city of the gaseous medium may be steady or may be suitably varied, for example

either between a first vel city producing no, or insufficient, fluid drag to propel the fibre member, and a second velocity producing sufficient fluid drag to propel the fibre member, or betw en a first and a second velocity both producing sufficient fluid drag for propelling the fibre member. Conveniently the variations in velocity take the form of repeated abrupt changes between the first and second velocity.

The forementioned variations in flow velocity may include periods during which the flow is reversed with respect to the desired direction of advance of the fibre member.

It is to be understood that more than one fibre member may be propelled along the same tubular pathway.

A fibre member may, for example, comprise a single optical fibre, protected by at least a primary coating but preferably contained within an outer envelope. Alternatively, a fibre member may comprise a plurality of optical fibres contained within a common envelope.

The envelope may be loosely or tightly surrounding the fibre or fibres.

The method may be used for insertion of an optical fibre member into, or its withdrawal, from the pathway.

The gaseous medium is chosen to be compatible with the environment in which the invention is performed, and in ordinary environments will be a non-hazardous gas or gas mixture.

With the proviso about compatibility with the environment, the gaseous medium is preferably air or nitrogen.

The tubular pathways and/or the fibre members are conveniently but not necessarily of circular cross-section, and the fibre member is always smaller than the pathway.

In practice the pathway internal diameter will generally be greater, and frequently much greater than 1 mm, and the external diameter of the fibre member greater than 0.5 mm.

A preferred range of diameters for the pathway is 1 to 10 mm, conveniently between 3 and 7 mm; and a preferred range of diameters for the fibre members is 1 to 4 mm, although much larger diameters may be used provided the fibre member is sufficiently lightweight and flexible. The diameter of the fibre members is preferably chosen to be greater than one tenth, and conveniently to be about one half of the pathway diameter or greater (and appropriately less, of course, if more than one fibre member is to be propelled through the same pathway).

Insertion of a fibre member by means of the fluid drag of a gas passing over the fibre member has several advantages over methods involving pulling an optical fibre cable with a pull cord.

Firstly, the extra step of providing a pull cord is eliminated.

Secondly, using the fluid drag of a gaseous medium produces a distributed pulling force on the fibre member. This is particularly advantageous if the installation route contains ne or more bends. If, as would be the case with a pulling cord, the pulling force were concentrated at the leading end of the fibre member, any deviation of the pathway from a straight line would greatly increase friction between the fibre member and the internal walls of the pathway, and only a few bends would be sufficient to cause locking of the fibre member. The distributed pulling force produced by the fluid drag, on the other hand, enables bends to be negotiated fairly easily, and the number of bends in a given installation is no longer of much significance.

Thirdly, the fluid drag substantially reduces overall pulling stress on the fibre member and so permits the fibre member to be of relatively simple and cheap construction.

Furthermore, because the fibre member is not subjected to any substantial pulling stress during installation, little allowance, if any, needs to be made for subsequent relaxation.

According to a further aspect of the present invention, a method of installing optical transmission lines comprises installing a conduit having one or more ductlets forming tubular pathways and inserting optical fibre members into associated ductlets by the aforesaid method.

The conduit may be rigid or flexible.

Where the conduit includes more than one ductlet, the ductlets are conveniently formed by bores in the material of the conduit. The term "bore", like the word "tubular" is understood in this context to include circular and other suitable shapes of cross-sectional area.

Alternatively, the conduit may comprise a plurality of individual tubes enveloped by a common outer sheath.

Installing optical fibre transmission lines by this method has several advantages over conventional techniques.

Firstly, since the conduit is installed without containing any optical fibres, conventional rope pulling and similar techniques may be freely employed for installing the conduit.

Secondly, the capacity of a transmission line can readily be adapted to requirements. Thus, while initially only one or two fibre members may be sufficient to carry the traffic the conduit may contain a much larger number of ductlets than are required at the time of installation, and further fibre members may be inserted later on as and when needed. The conduit of the present invention is cheap compared to the cost of the fibres, and spare ductlets to accommodate further fibres as and when extra capacity is required can thus be readily incorporated without adding more than a small fraction to overall costs.

The method of the present invention also permits the installation of improved later generations of optical fibre transmission lines. It is possibl , for example, to install at first one or more fibre members incorporating multimode fibres, and at a later date add, or replace the install d multimode fibre members with fibre members incorporating monomode fibres. Installed fibre m mbers may conveniently be

withdrawn from the ductlet, and r placement fibre members be inserted by using the aforesaid method of propelling by fluid drag of a gaseous medium.

It will be appreciated that th present inv ntion larg ly avoids the risk, inherent in handling optical fibre cables with a large number of fibres, of accidentally damaging before or during installation in a single event a large number of expensive optical fibres.

The present invention also enables the installation of continuous optical fibres over several installation lengths without joints.

Furthermore, individual fibre members routed through the conduit can be routed, without requiring fibre joints, into different branch conduits at junction points.

The present invention will now be explained further by way of example and with reference to the accompanying drawings of which;

Figure 1 is a cross section through a conduit suitable for implementing the invention;

Figures 2 and 3 are relatively enlarged cross-sections through fibre members;

Figure 4 is a schematic diagram of apparatus for inserting fibre members into ductlets by fluid drag;

Figure 5 is a schematic drawing of a junction between a trunk and a branch conduit;

Figure 6 is a schematic diagram to illustrate notation used in drag force calculations;

Figure 7 is a schematic section of a modified drive unit; and

Figure 8 is a graph of drag force vs pressure.

Referring first to the Figure 1, there is shown a conduit 11 incorporating six ductlets 12, one of which contains a fibre member 14, and a core 13.

The conduit 11 is made of extruded polymer or other suitable material, the ductlets, or bores, 12 being formed in the conduit during its extrusion. The central core 13 contains copper wire pairs required for testing operations during and after installation, repeater supervision, power supply, and the like. Alternatively, or additionally, the core 13 may incorporate reinforcements, for example tension wires, to take up the tension forces during installation of the conduit.

Where required, the conduit may be surrounded by a water barrier (not shown).

The copper wire pair for testing can be omitted from the core 13 if suitable alternative testing facilities are available, such as, for example testing methods using optical fibres inserted subsequently into the conduit as described below.

Figure 2 is a cross-section through a fibre member 21 which is in a form particularly suited for installation by fluid drag. The fibre member 21 comprises several optical fibres 22 lying loosely in a polymer sheath 23. In view of the virtual absence of any pulling stress during installation of a fibre member by fluid drag, the fibre member 21 does not require reinforcement. The relatively simple construction also leads to lower producti n costs, as well as making the fibre member 21 comparatively light, thereby enabling easy installation by fluid drag.

In certain circumstances, it may be desirable to provide a reinforced fibre m mber, and Figure 3 is a cross-section through such a fibre member 31 which, provided it is made light enough and flexible enough, is suitabl for insertion by fluid drag into a ductlet 12 of the conduit 11 of Figure 1. The fibre member 31 consists of a plurality of optical fibres 32 arranged round a strength member 33 and enclosed in a polymer sheath 34.

The instllation of an optical transmission line proceeds as follows:

The flexible conduit 11 is installed into an existing duct (not shown) by conventional methods such as pulling with a pulling rope.

Because the conduit 11 does not contain any optical fibres at this stage, the conduit 11 can be handled in the same way as an ordinary cable, and no special care needs to be taken over and above that customary in installing conventional metal conductor cables. If required, it is also possible at this stage, that is before the conduit contains any optical fibres, to pull a further conduit through the duct to provide spare capacity.

Furthermore, since the conduit can readily be made of an external diameter matching that of cables already in the duct, wedging is less likely to occur than with a standard, smaller diameter optical fibre cable.

Once installed, optical fibre members such as 21 and 31 shown in Figure 2 or 3 are inserted into as many of the ductlets 12 as is required.

Instead of the afore-described fibre members 21 and 31 of near circular cross-section, the fibre members may, for example, be so-called ribbons, in which a thin, wide sheath encloses an optical fibre or a plurality of optical fibres lying in the same plane.

Manufacture of the conduit 11 is cheap compared to the optical fibres in the fibre members 21 or 31 which it is designed to carry, and spare ductlets 12 for future expansion can readily be incorporated at the extrusion stage of the conduit 11 without adding unduly to the overall cost. The conduit may be manufactured by adapting conventional cable manufacturing processes such as, for example, extrusion.

A gas flowing past the surface of a solid object produces a drag force which largely depends on the velocity of the gas relative to the surface. The Applicants have found that this drag force can be made sufficiently large to pull a lightweight optical fibre member 21, or 31 into a tubular pathway such as, for example, a ductlet 12 of the aforementioned conduit 11.

In experiments, the flow velocity, or the flow rate, of air through a given pathway has been found to depend approximately linearly on the pressure difference between opposite ends of the pathway, with the slope of the dependency indicating that flow at useful flow rates is predominantly turbulent.

For a given pr ssure difference, th flow rate

varies with the size of the free cross sectional area of the bore, while the drag force on a fibre member present in a bore varies with the flow rate and th surface area of the fibre member. The drag force has been optimis d in experiments by varying these parameters and, in particular, by choosing an appropriate ratio of bore diameter to fibre member diameter.

Experiments have been performed using a bore diameter of 7 mm. The optimum fibre member diameter for this bore size has been found to lie between 2.5 and 4 mm. A pressure below 80 p.s.i. (approximately 5.6 kg/cm^2), usually about 40 p.s.i. has been found sufficient to insert fibre members of up to 3.5 gram per metre (gr/m) over lengths of 200 metres. A fibre member with 2 gr/m is easily installed over this length.

The theoretical value of the drag forces for these dimensions has been calculated in the manner described below with reference to Figure 6 to be 2.5 gr/m. Lower practical values are believed to be due to the tendency of the fibre members 21, 31 to acquire "set" while on the supply reel. This set would appear to force the fibre member 21, 31 against the wall of the bore 12, thereby increasing friction.

Suitable texturing or shaping of the fibre member surface may lead to drag forces higher than those presently experienced.

It should be noted here that using fluid drag to insert fibre members into tubular pathways differs significantly from the method described in the above mentioned article of inserting pull cords by means of parachutes. The parachute is propelled by the pressure difference between the air in front of the air behind the parachute, and the velocity of the air relative to the advancing cord is only minimal and the pulling force is localised at the point of attachment of the parachute. In contrast, using fluid drag requires a relatively high flow of fluid relative to the surface of the fibre members.

Also, unlike the use of parachutes or potential other methods of inserting fibre members into the tubular pathways, using fluid drag produces a uniformly distributed pulling force on the fibre member. This reduces the strain on the optical fibres within the fibre member to very low values.

In ordinarily pulling a fibre member through a bend enclosing an angle θ, the tension of the leading end, T_2 is related to the tension T_1 at the trailing end $T_2/T_1=e^{\mu\theta}$ where μ is the coefficient of friction. Even a small number of bends in the pathway may therefore result in an unacceptably high force being required at the leading end if locking of the fibre member is to be avoided. In contrast, the distributed pulling force produced by fluid drag is applied evenly along the fibre member, including in bends, and permits a large number of bends to be easily and speedily negotiated without any undue stress on the fibre member.

Figure 4 illustrates apparatus for feeding fibre members into tubular pathways such as the ductlets 12 of the conduit 11 of Figur 1. The apparatus consists of a feedhead 41 which contains a straight bore 44 connected at one end, its outlet end 42, to a flexible tube 49, and at the other nd, its inl t nd 43, to a supply reel (not shown). The head 41 also contains an inlet 45 for air. The outlet end 42 and th bore 44 are substantially larger in cross sectional area than fibre member 46. The aperture of the inlet end 43 is only slightly larger in cross sectional area than that of the fibre member 46. This arrangement forms an air block which presents a relatively large flow resistance to air and helps prevent air escaping through the inlet duct 43. The tube 49 is inserted into one of the ductlets of the conduit 11. Suitable seals between the feedhead 41 and the tube 49, and the tube 49 and the ductlet 12 prevent undesirable escape of the air.

In use the fibre member 46 is fed into the inlet end 43 of the feedhead 41 by means of a pair of rubber drive wheels 47 and 48, driven by a constant torque driving mechanism (not shown). Air is fed into the bore 44 through the air inlet 45 and hence is directed through the tube 49 into the ductlet 12. The optical fibre member 46 is pushed through the inlet end 43 of the feedhead into the bore 44 and onwards into the tube 49. Pushing of the fibre member 46 continues until the surface area of the fibre member which is exposed to the air flow is sufficiently large to produce a drag force to cause the further advance of the fibre member 46 through the tube 49 and the ductlet 12, while the rate of feed is controlled by means of the aforementioned rubber drive wheels 47 and 48.

Figure 5 shows a branching connection between an optical fibre trunk line 51 and a branch line 52, each comprising a conduit 53 and 54 respectively and one or more fibre members 55 and 56. Since, as described above, the fibre members are individually inserted into the ductlets of the trunkline conduit 53, individual fibre members 55 can be routed from the trunk conduit 53 into the branch conduit 54 as required, while other fibre members 56 continue to the adjacent section 53a of the trunkline conduit.

Referring now also to Figure 6, the drag force on the fibre member 64 within the bore 63 of a ductlet, or tube, 62 on account of turbulent air flow through the bore 63 can be calculated as discussed below.

These calculations show that what has been called fluid drag or drag force above is, in fact, a composite force, of which the major proportion is normally due to viscous drag, and at least one another important component due to a hydrostatic force, f' below. It will be appreciated that the exact composition of the drag force does not affect the principles of the invention but the more detailed analysis below can be used to optimise the parameters involved in carrying out the invention, and to obtain some guidance for trial and error experiments.

The pressure difference between the tube ends can be equated to a shear force distributed ver the inner surface of the bore 63 and the uter

surface of the fibre member 64. Thus, one has, for a small element f length Δl producing a pressure drop Δp

$$\Delta p\pi(r_2^2-r_1^2)=F \qquad (1)$$

where r_2=outer tube bore radius, r_1=inner tube radius and F is the viscous drag force on the inner and outer walls of the elemental length.

If it is now assumed that the force F is distributed evenly over the area of the inner and outer walls, that is to say the external wall of the fibre member and the internal wall of the ductlet respectively, the drag force, f, on the fibre member per unit length is:—

$$f=\frac{F}{\Delta l}\left[\frac{2\pi r_1}{2\pi(r_1+r_2)}\right]=\frac{\Delta p}{\Delta L}\pi r_1(r_2-r_1) \qquad (2)$$

which gives, in the limit, the drag force on the fibre member per unit length,

$$f=\pi r_1(r_2-r_1)\frac{dp}{dl} \qquad (3)$$

In addition, we must consider the force produced by the pressure difference acting on the cross-sectional area of the fibre member. This is locally proportional to the pressure gradient and therefore is distributed over the installed length of the fibre member in the same way as the viscous drag force, leading to an additional force

$$f'=\frac{\Delta p}{\Delta l}\pi r_1^2 \qquad (4)$$

giving a total force per unit length of

$$f_{TOT}=\frac{dp}{dt}\pi r_1 r_2 \qquad (5)$$

In order to get an initial estimate of this it is assumed that the pressure drops linearly over the length of the bore, whether filled by the fibre member or not. Equation 5 is then plotted, for the case of the 6 mm bore diameter with 2.5 mm O.D. fibre member, in Figure 8, for a length of 300 m. Since pressure is normally quoted in psi it has been retained here for the sake of convenience.

Coefficients of friction of around 0.5 have been measured for the polyethylene and polypropylene fibre members against a polyethylene bore wall. Therefore, with a fibre member weighing 3 gms/m we could expect to install a 300 m length with around 55 psi pressure. Any extra drag force over that required to overcome friction would appear at the start end as a gradually increasing tension in the fibre member as installation proceeds.

Figure 7 shows in diagrammatic form the arrangement of the modified drive unit discussed with reference to Figure 4, in which the only major change li s in incorp rating the drive wh els 77 and 78 within the feedhead 71.

As the foregoing discussion with reference to Figure 6 has illustrated, the viscous drag force is accompanied by a hydrostatic force, the force f' of equation 5 above. This force f' has been found to oppose the insertion of the fibre member into the drive unit, making the incorporation of the drive wheels 77 and 78 into the drive unit preferable. The force f', referred above as the hydrostatic potential must be overcome when introducing the fibre member into the pressurised areas. The drive wheels would be driven by a torque just sufficient to overcome this potential.

The drive wheels are incorporated into the pressurised cavity 74 and thus the force on the fibre member necessary to overcome the hydrostatic potential is tensile. If the wheels were outside the drive unit, this force would be compressive, and there would be tendency for the fibre member to buckle.

For convenience the drive unit may be made to split along the fibre member axis, and perpendicular to the diagram, or in some other plane. The air seals 72, 73 may be, for example, rubber lips, or narrow channels.

In operation, a fibre member 76 fed into the drive unit would be automatically taken up by the drive wheels with just enough force to overcome the hydrostatic potential, and fed on along the ductlet 12. The fluid drag of the air flowing down the ductlet 12 causes the fibre member 76 to be pulled along the ductlet 12 as the installation proceeds. This means that such a drive unit can be placed between two adjoining sections of conduit so that a fibre member emerging from a ductlet in the first conduit can be fed into the appropriate ductlet of the second. Thus, an installation could consist of a fibre member 76 running through a number of conduits using two or more drive units in tandem, possibly without supervision.

It will be appreciated that it is possible to blow compounds in liquid or powder form along the ductlet prior to, or during installation in order to provide lubrication for the fibre members. Powdered talc is an example of a suitable lubricant.

The ductlets may, for example, also be formed in a power cable, or in a conventional subscriber line, to allow subsequent installation of optical fibre members. In the latter case, to avoid ingress of water, the ductlet may be sealed until the time of installation of the fibre members.

Claims

1. A method of providing an optical communications route by moving a lightweight and flexible optical fibre transmission line (14) comprising one ptical fibres along a previously installed tubular pathway (12) in situ, characterised in that the transmision line (14) is propelled along the pathway (12) by fluid drag of

a gaseous medium passed through the pathway (12) in the desired direction of movement and passing over the transmission line at a relatively high average flow velocity.

2. A method as claimed in claim 1 wherein the gaseous medium is passed through the pathway (12), at a steady flow velocity.

3. A method as claimed in claim 1 wherein the gaseous medium is passed through the pathway (12) at a flow velocity which is repeatedly changed abruptly between a first and second velocity.

4. A method as claimed in any preceding claim wherein the gaseous medium is compressed air.

5. A method as claimed in any preceding claim wherein the gaseous medium is nitrogen.

6. A method of installing optical transmission lines comprising installing a conduit having one or more ductlets (12) forming tubular pathways, and inserting optical fibre members (14) into associated ductlets (12) in the manner of any one of claims 1 to 5.

7. A method as claimed in claim 6 wherein the conduit (11) is a flexible conduit installed by a conventional cable installation technique.

8. A method as claimed in any preceding claim using optical fibre members (14) and tubular pathways (12) of circular cross-section.

9. A method as claimed in any preceding claim using optical fibre members of a diameter greater than one tenth the diameter of the tubular pathway.

10. Apparatus for advancing an optical fibre along a previously installed tubular pathway in situ in the manner of any one of claims 1 to 9, the apparatus comprising a feed head (41, 71) having a hollow substantially rectilinear passage (44, 74) extending therethrough, said passage being provided with an inlet end (43, 73) and an outlet end (42, 72) to receive and dispense respectively an optical fibre member (46, 76), and the outlet end (42, 72) being arranged to provide sealing coupling to a tubular pathway, having a further passage (45, 75) to supply a gaseous medium to said passage (44, 74), and being provided with a pair of constant torque driven wheels (47, 48; 77, 78) adapted to engage and control advance of the optical fibre member (46, 76) towards the tubular pathway (12).

11. Apparatus as claimed in claim 10 wherein said drive wheels (77, 78) are located within the feedhead (71).

12. Apparatus as claimed in claim 10 or 11 arranged to split along the fibre member axis, thereby to facilitate removal from or placement of said apparatus around the fibre member (46, 76).

Patentansprüche

1. Verfahren zum Bewegen ein r leichtgewichtig n und flexiblen optischen Üb r-tragungsfaserleitung (14), die ein oder mehrere optische Fasern aufweist, entlang ein s vorher installierten röhrenförmigen Weges (12) in situ, wodurch eine optische Übertragungsstrecke gebildet wird, dadurch gekennzeichnet, daß die Übertragungsleitung (14) vorwärts getrieben wird entlang des Weges (12) durch fluides Schleppen eines gasförmigen Mediums, das durch den Weg (12) in der gewünschten Bewegungsrichtung geführt wird, und das b i einer relativ hoh n durchschnittlichen Fließgeschwindigkeit über die Übertragungsleitung geführt wird.

2. Verfahren nach Anspruch 1, worin das gasförmige Medium durch den Weg (12) bei einer gleichförmigen Fließgeschwindigkeit geführt wird.

3. Verfahren nach Anspruch 1, worin das gasförmige Medium durch den Weg (12) bei einer Geschwindigkeit geführt wird, die wiederholt abrupt verändert wird zwischen einer ersten und einer zweiten Geschwindigkeit.

4. Verfahren nach einem der vorhergehenden Ansprüche, worin das gasförmige Medium komprimierte Luft ist.

5. Verfahren nach einem der vorhergehenden Ansprüche, worin das gasförmige Medium Stickstoff ist.

6. Verfahren Installieren von optischen Übertragungsleitungen, das das Installieren einer Rohrleitung, die ein oder mehrere Kanälchen (12) aufweist, die röhrenförmige Wege bilden, und das Einführen von optischen Fasergliedern (14) in zugeordnete Kanälchen (12) in der Art von einem der Ansprüche 1 bis 5 aufweist.

7. Verfahren nach Anspruch 6, worin die Rohrleitung (11) eine flexible Rohrleitung ist, die durch konventionelle Leitungsinstallationstechnik installiert wird.

8. Verfahren nach einem der vorhergehenden Ansprüche, das optische Faserglieder (14) und röhrenformige Wege (12) von kreisförmigem Querschnitt verwendet.

9. Verfahren nach einem der vorhergehenden Ansprüche, das optische Faserglieder eines Durchmessers verwendet, der größer ist als ein Zehntel des Durchmessers des röhrenförmigen Weges.

10. Vorrichtung zum Vorantreiben einer optischen Faser entlang eines vorher installierten röhrenförmigen Weges in situ in der Art einer der Ansprüche 1 bis 9, wobei die Vorrichtung einen Zuführkopf (41, 71) aufweist, der einen hohlen, im wesentlichen geradlinigen Durchgang (44, 74) aufweist, der sich dadurch hindurch erstreckt, wobei der Durchgang mit einem Einlaßende (43, 73) und einem Auslaßende (42, 72) versehen ist, um ein optisches Faserglied (46, 76) aufzunehmen bzw. auszugeben, und das Auslaßende (42, 72) so angeordnet ist, daß es eine dichtende Kupplung zu einem röhrenförmigen Weg liefert, der einen weiteren Durchgang (45, 75) aufweist, um ein gasförmiges Medium zu diesem Durchgang (44, 74) zuzuführ n, und der versehen ist mit ein m Paar von Rädern (47, 48; 77, 78), die mit konstantem Drehmom nt angetrieben sind, die geeignet sind, um mit dem optischen Faserglied (46, 76) in Eingriff zu stehen und seinen Vorschub in Richtung auf den röhrenförmigen Weg (12) zu steuern.

11. Vorrichtung nach Anspruch 10, worin die Antriebsräder (77, 78) innerhalb des Zuführkopfes (71) angeordnet sind.

12. Vorrichtung nach Anspruch 10 oder 11, die eingerichtet ist, um entlang der Achse des Fasergliedes getrennt zu werden, um dadurch das Entfernen der Vorrichtung von oder das Plazieren um das Faserglied (46, 76) zu erleichtern.

Revendications

1. Un procédé pour entraîner une ligne de transmission (14) à fibres optiques de poids léger et flexible comprenant une ou plusieurs fibres optiques le long d'un passant tubulaire (12) préalablement installé in situ, de façon à créer un trajet de communication optique, caractérisé en ce que la ligne de transmission (14) est propulsée le long du passage (12) par frottement fluidique exercé par un milieu gazeux s'écoulant dans le passage (12) dans la direction désirée de mouvement et passant sur la ligne de transmission avec une vitesse d'écoulement moyenne relativement grande.

2. Un procédé tel que revendiqué dans la revendication 1, selon lequel le milieu gazeux passe dans le passage (22) à une vitesse d'écoulement stable.

3. Un procédé tel que revendiqué dans la revendication 1, selon lequel le milieu gazeux passe dans le passage (12) à une vitesse d'écoulement qui est modifiée de façon répétée et bruquement entre une première et une seconde vitesse.

4. Un procédé tel que revendiqué dans l'une quelconque des revendications précédentes, selon lequel le milieu gazeux est de l'air comprimé.

5. Un procédé tel que revendiqué dans l'une quelconque des revendications précédentes, selon lequel le milieu gazeux est de l'azote.

6. Un procédé d'installation de lignes de transmission optique, consistant à installer un conduit comportant un ou plusieurs passages (12) formant des trajets tubulaires, et à insérer des éléments à fibres optiques (14) dans des passages associ´s (12) selon la manière définie dans l'une quelconque des revendications 1 à 5.

7. Un procédé tel que revendiqué dans la revendication 6, selon lequel le conduit (11) est un conduit flexible installé par une technique classique d'installation de câbles.

8. Un procédé tel que revendiqué dans l'une quelconque des revendications précédentes, utilisant des éléments à fibres optiques (14) et des passages tubulaires (12) de section droite circulaire.

9. Un procédé tel que revendiqué dans l'une quelconque des revendications précédentes, utilisant des éléments à fibres optiques d'un diamètre supérieur à un dixième du diamètre du passage tubulaire.

10. Appareil pour faire avancer une fibre optique le long d'un passage tubulaire installé antérieurement in situ de la manière définie dans l'une quelconque des revendications 1 à 9, l'appareil comprenant une tête d'avancement (41, 71) pourvue d'un passage creux sensiblement rectiligne (44, 74) la traversant, ledit passge étant pourvu d'une extrémité d'entrée (43, 73) et d'une extrémité de sortie (42, 72) pour assurer respectivement la réception et la décharge d'un élément à fibre optique (46, 76), et l'extrémité de sortie (42, 72) étant agencée de façon à établir un raccordement étanche avec un conduit tubulaire, comportant un autre passage (45, 75) pour alimenter en milieu gazeux ledit passage (44, 74), et étant pourvue de deux roues (47, 48; 77, 78) entraînées avec un couple constant et adaptées pour s'appliquer contre et commander l'avance de l'élément à fibres optiques (46, 76) en direction du conduit tubulaire (12).

11. Appareil tel que revendiqué dans la revendication 10, caractérisé en ce que lesdites roues d'entraînement (77, 78) sont placées à l'intérieur de la tête d'avancement (71).

12. Appareil tel que revendiqué dans la revendication 10 ou 11, agencé pour être divisé le long de l'axe de l'élément à fibres, en facilitant ainsi la mise en place dudit appareil autour de l'élément à fibres (46, 76) et son enlèvement.

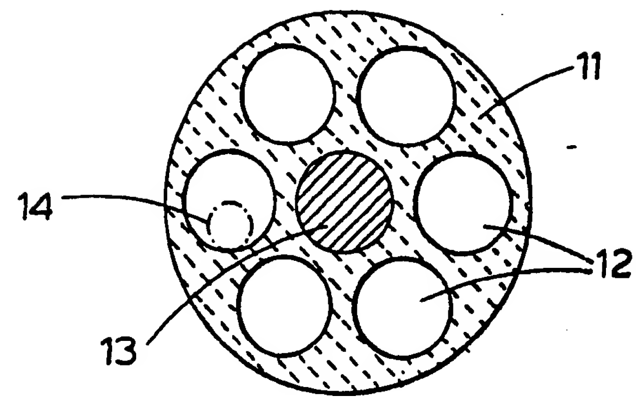

Fig. 1

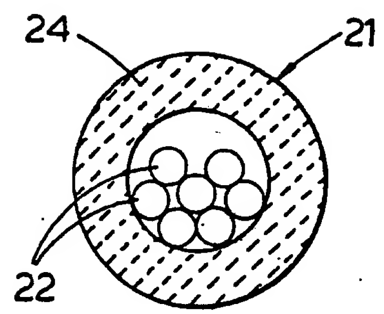

Fig. 2

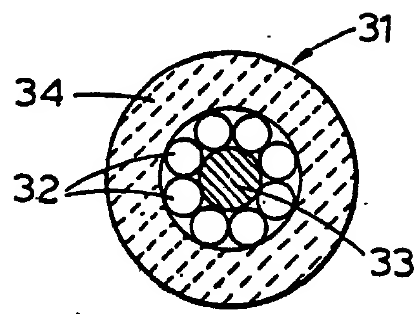

Fig. 3

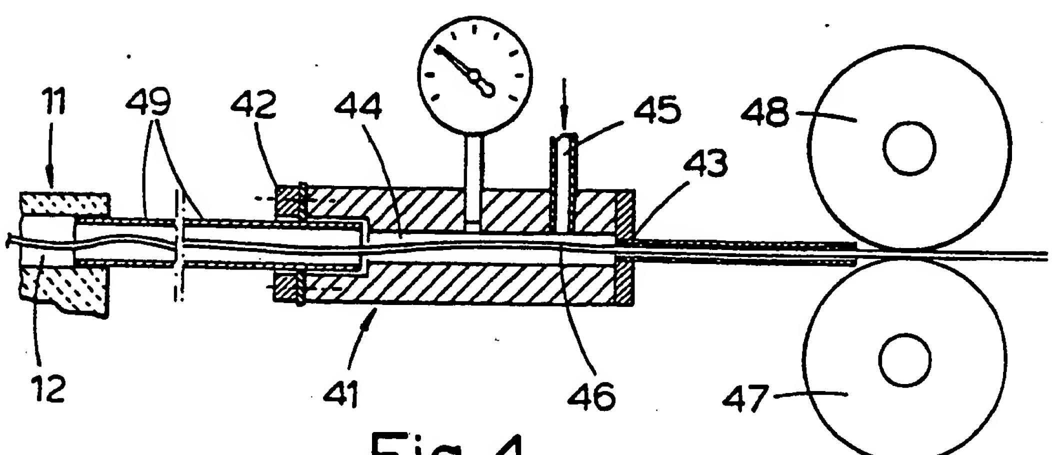

Fig. 4

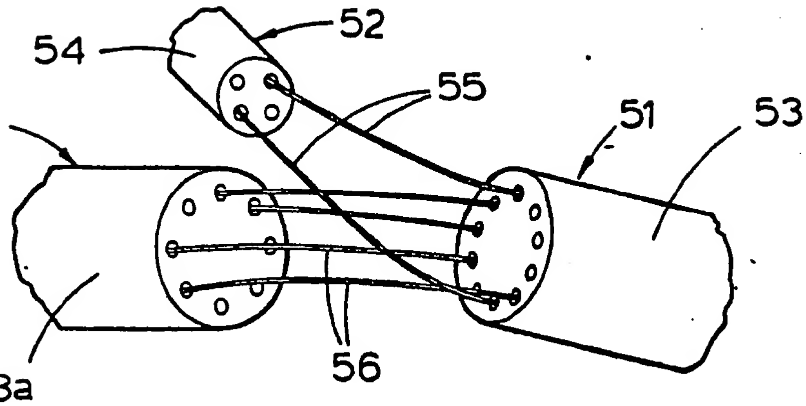

Fig. 5

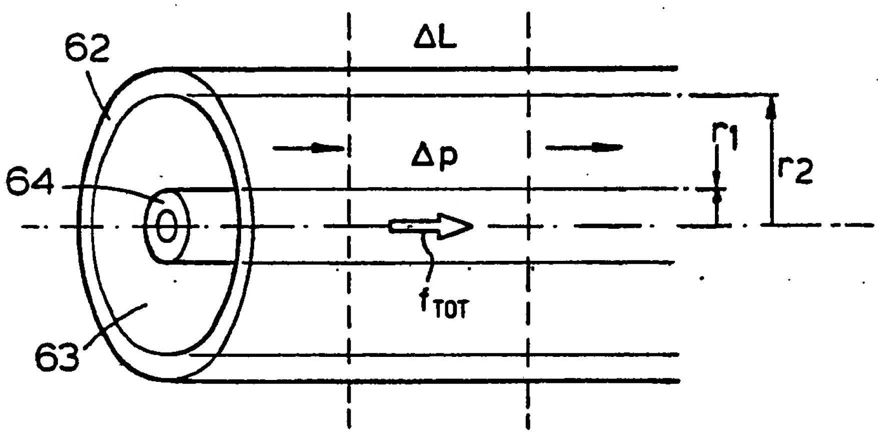

Fig. 6

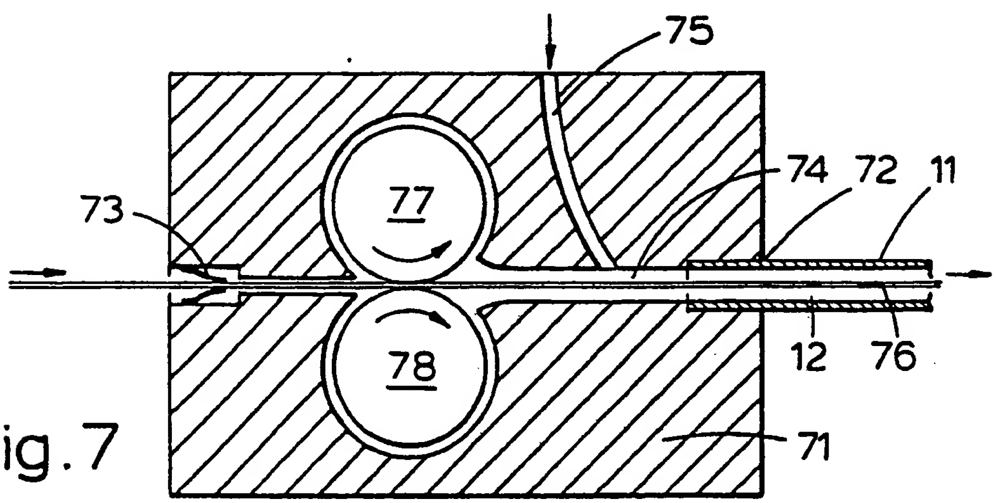

Fig. 7

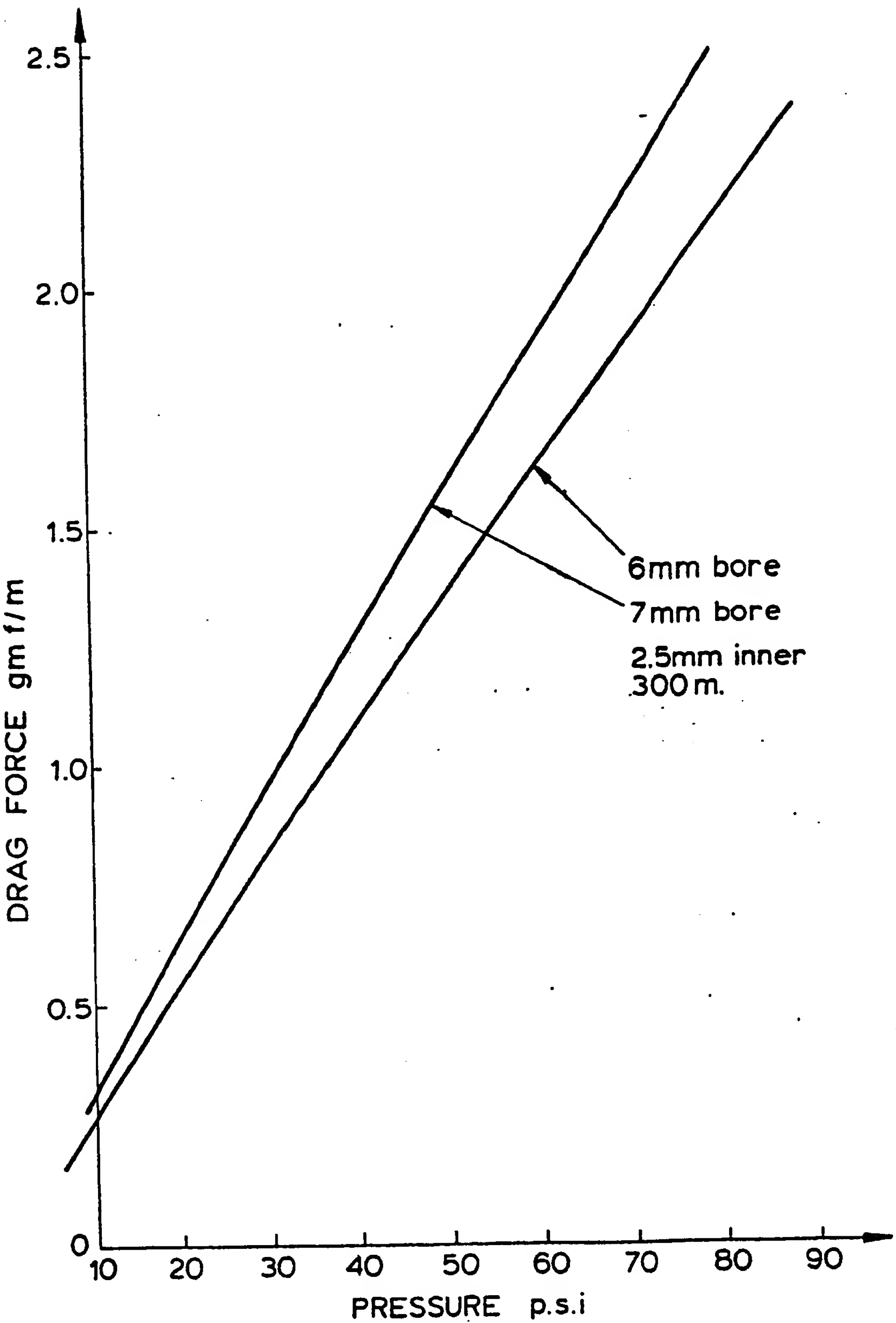
2.5
2.0
1.5
1.0
0.5
0
DRAG FORCE gm f/m
6mm bore
7mm bore
2.5mm inner
.300 m.
10
20
30
40
50
60
70
80
90
PRESSURE p.s.i

Fig. 8